# 6. HUMAN HEALTH BASELINE RISK ASSESSMENT

The WAG 4 BRA is the first of a two part evaluation. The second part is the ecological risk assessment (ERA) (see Section 7). The human health risk assessment approach used in the BRA is based on the *Risk Assessment Guidance for Superfund (RAGS),* (EPA 1989a), the *INEL Track 2 Guidance Document* (DOE-ID 1994), and the *INEL Cumulative Risk Assessment Guidance Protocol* (LMITCO 1995).

Preliminary evaluations of both human health and ecological risks at WAG 4 have been completed as part of the *Work Plan for Waste Area Group 4 Operable Unit 4-13 Comprehensive Remedial Investigation Study* (DOE-ID 1997). The WAG 4 Human Health Contaminant Screening (Section 3.4 of the OU 4-13 Work Plan) was developed as a preliminary evaluation of WAG 4 human health risks.

A discussion of general comprehensive risk assessment methodologies is presented in the *INEL Cumulative Risk Assessment Guidance Protocol* (LMITCO 1995). The analysis methods used in INEEL comprehensive risk assessments are often different from the analysis methods used in *INEL Track 1 and Track 2 Risk Assessments* (DOE-ID 1994). The differences between the two types of analyses are present because comprehensive risk assessments analyze risks produced by multiple release sites within a WAG, while Track 1 and Track 2 risk assessments analyze risks from one release site at a time.

To satisfy the broader objective of INEEL comprehensive risk assessments, the *INEL Cumulative Risk Assessment Guidance Protocol* recommends analyzing risks produced through the air and groundwater exposure pathways in a "cumulative" manner. A cumulative analysis of these two exposure pathways involves calculating one WAG-wide risk number for each contaminant of potential concern (COPC) for each air and groundwater exposure route (e.g., inhalation of fugitive dust, ingestion of groundwater, etc.). Analyzing the air and groundwater pathways in a cumulative manner is necessary because contamination from all release sites within a WAG may affect air and groundwater exposure pathways at the WAG. Conversely, individual release sites within a WAG are typically isolated from one another with respect to the soil pathway exposure routes (e.g., ingestion of soil, ingestion of homegrown produce, etc.). As a result, the guidance protocol recommends analyzing soil pathway exposures on a release-site-specific, or "noncumulative" basis in INEEL comprehensive risk assessments.

The details of the "comprehensive" and "cumulative" aspects of the WAG 4 BRA are discussed in more detail in the following sections. In general, the BRA is "comprehensive" because it evaluates risks from all known and potential release sites within WAG 4, and it is "cumulative" because risks from multiple release sites are evaluated for the air and groundwater exposure pathways.

The term "risk" is used throughout this section in a generic sense. Generally the term is used to refer to the possibility of adverse health effects from either carcinogenic or noncarcinogenic contaminants, however, it is also used when only carcinogenic health effects are being discussed. The terms "noncancer risk," "hazard quotient" (HQ), and "hazard index" (HI) are used only when noncarcinogenic health effects are discussed.

## 6.1 Baseline Risk Assessment Tasks

The tasks associated with development of the WAG 4 human health BRA are activities as follows:

- Data evaluation, including site and contaminant screening

- Exposure assessment
- Toxicity assessment
- Risk characterization
- Uncertainty analysis.

These tasks are described in the following subsections.

### 6.1.1 Perform Data Evaluation

All analytical data collected to date at WAG 4 release sites (see Section 4 for a discussion of the various WAG 4 investigations) were evaluated to determine whether the data are appropriate and adequate for use in the BRA. This evaluation was conducted in accordance with *EPA's Guidance for Data Usability in Risk Assessment* (EPA 1992a). As part of this analysis, sampling data sets were assumed to have lognormal distributions in accordance with *EPA's Guidance on Calculating Concentration Terms* (EPA 1992b); however, statistical distributions for the data were not determined.

The data evaluation tasks that were completed as part of the BRA are as follows:

- Screen of release sites to identify sites that have the potential to produce adverse human health and ecological impacts (see Section 6.2.1 for a discussion of the site screening process).
- Review of available sampling data for the retained release sites. This review included a "process knowledge" evaluation designed to identify any contaminants that may have been released at a given site but not sampled for.
- Identification of contaminants detected at each retained release site and screened to identify COPCs (see Section 6.2.2 for a discussion of the contaminant screening process).
- Identification of potential exposure routes for each COPC.
- Development of data set for use in the risk assessment.

The results of the data evaluation tasks are presented in Section 6.2.

### 6.1.2 Conduct Exposure Assessment

The process of exposure assessment quantifies all receptor intakes of COPCs for selected pathways. The assessment consists of estimating the magnitude, frequency, duration, and exposure route of COPCs to humans and ecological receptors. The following exposure assessment tasks were performed as part of the BRA process:

- Identification and characterization of exposed populations
- Identification of complete exposure pathways

- Estimation of contaminant concentrations at points of exposure
  - Soil pathway
  - Air pathway
  - Groundwater pathway.
- Estimation of human intake rates
- Calculation of intake factors.

The conceptual site models (CSMs) used to develop the BRA exposure assessment are presented in Figures 6-1 through 6-3, and the results of the exposure assessment tasks are presented in Section 6.3.

### 6.1.3 Conduct Toxicity Assessment

Toxicity assessment is the process of characterizing the relationship between the dose or intake of a substance and the incidence of an adverse effect in the exposed population. Toxicity assessments evaluate results from studies with laboratory animals, or from human epidemiological studies. These evaluations are used to extrapolate from high levels of exposure, where adverse effects are known to occur, to low levels of environmental exposures, where effects can only be predicted based on statistical probabilities. The results of these extrapolations are used to establish quantitative indicators of toxicity.

Health risks from all routes of exposure are characterized by combining the chemical intake information with numerical indicators of toxicity. These health-protective toxicity criteria are obtained through Environmental Protection Agency (EPA)-developed reference doses (RfDs) or slope factors (SFs). The information used as part of the BRA toxicity assessment is presented in Section 6.4.

### 6.1.4 Risk Characterization

Risk characterization involves combining the results of the toxicity and exposure assessments to provide a numerical estimate of health risk. This estimate is either a comparison of exposure levels with appropriate toxicity criteria, or an estimate of the lifetime cancer risk associated with a particular intake. Risk characterization also considers the nature and weight of evidence supporting the risk estimate, as well as the magnitude of uncertainty surrounding the estimate. The results of the BRA risk characterization process, including risk estimates for each of the retained release sites, are presented in Section 6.5. Uncertainties associated with risk estimates are presented in Section 6.6.

## 6.2 Site and Contaminant Screening

This section presents the site and contaminant screening methodologies used in the WAG 4 BRA. These screening methodologies are used to help focus the BRA by identifying release sites and contaminants that do not contribute to the comprehensive human health or ecological risk at WAG 4. The screening methodologies are designed to be conservative so that only sites and contaminants that clearly do not pose any threat of producing adverse human health or ecological effects are identified by the methodologies.

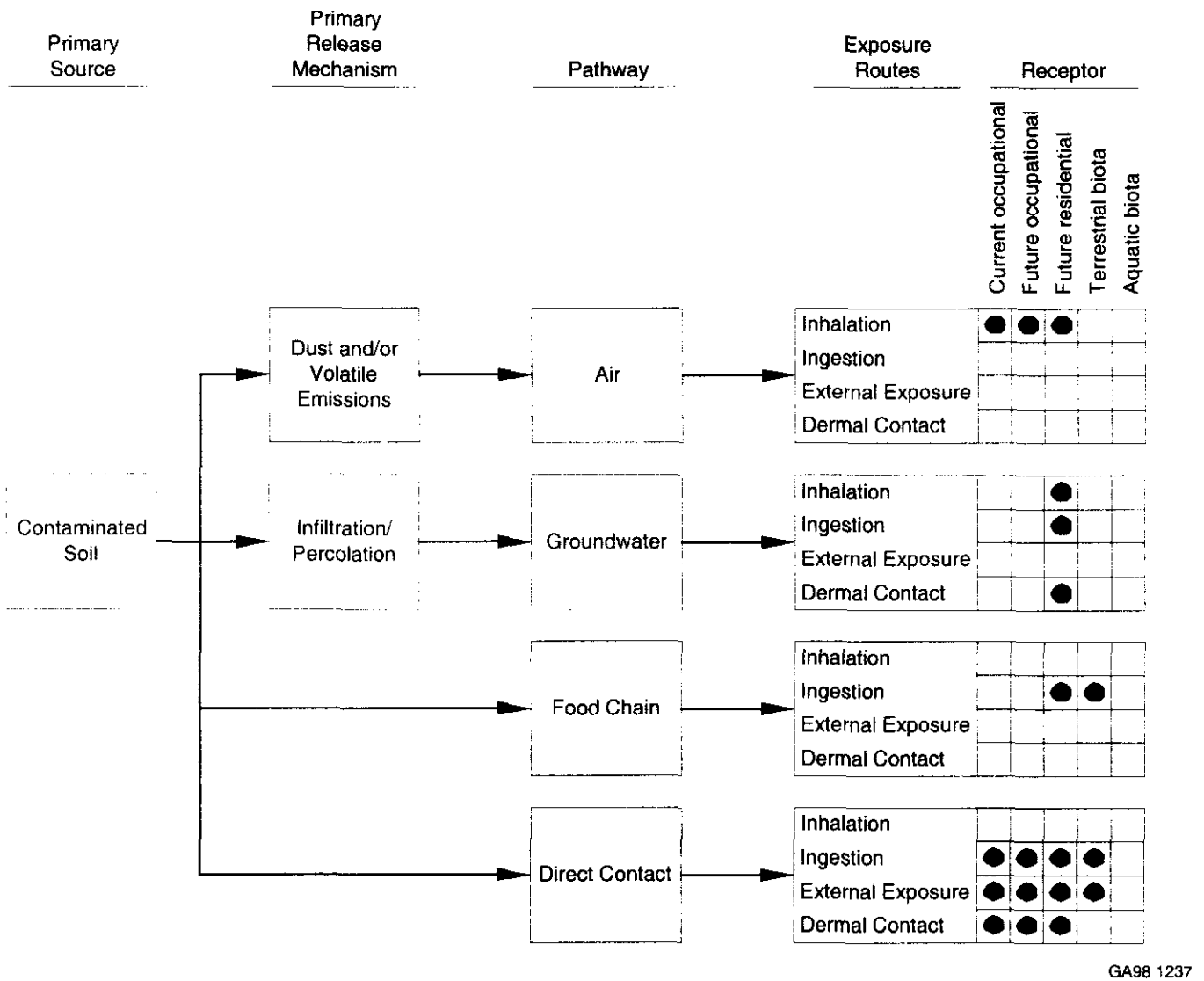


**Figure 6-1.** Conceptual site model for contaminated surface soil sites at CFA.

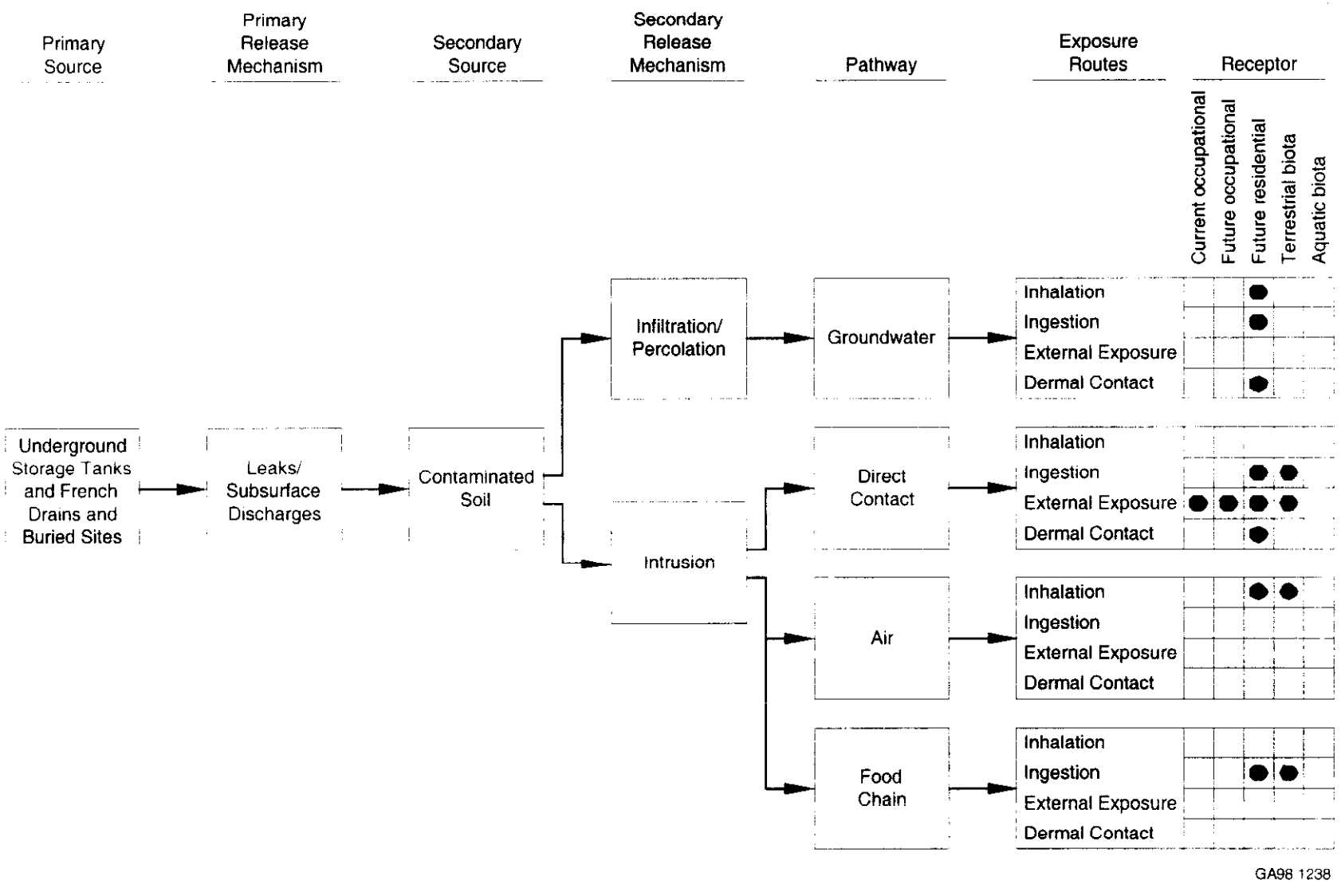


**Figure 6-2.** Conceptual site model for underground storage tanks and buried waste sites at CFA.

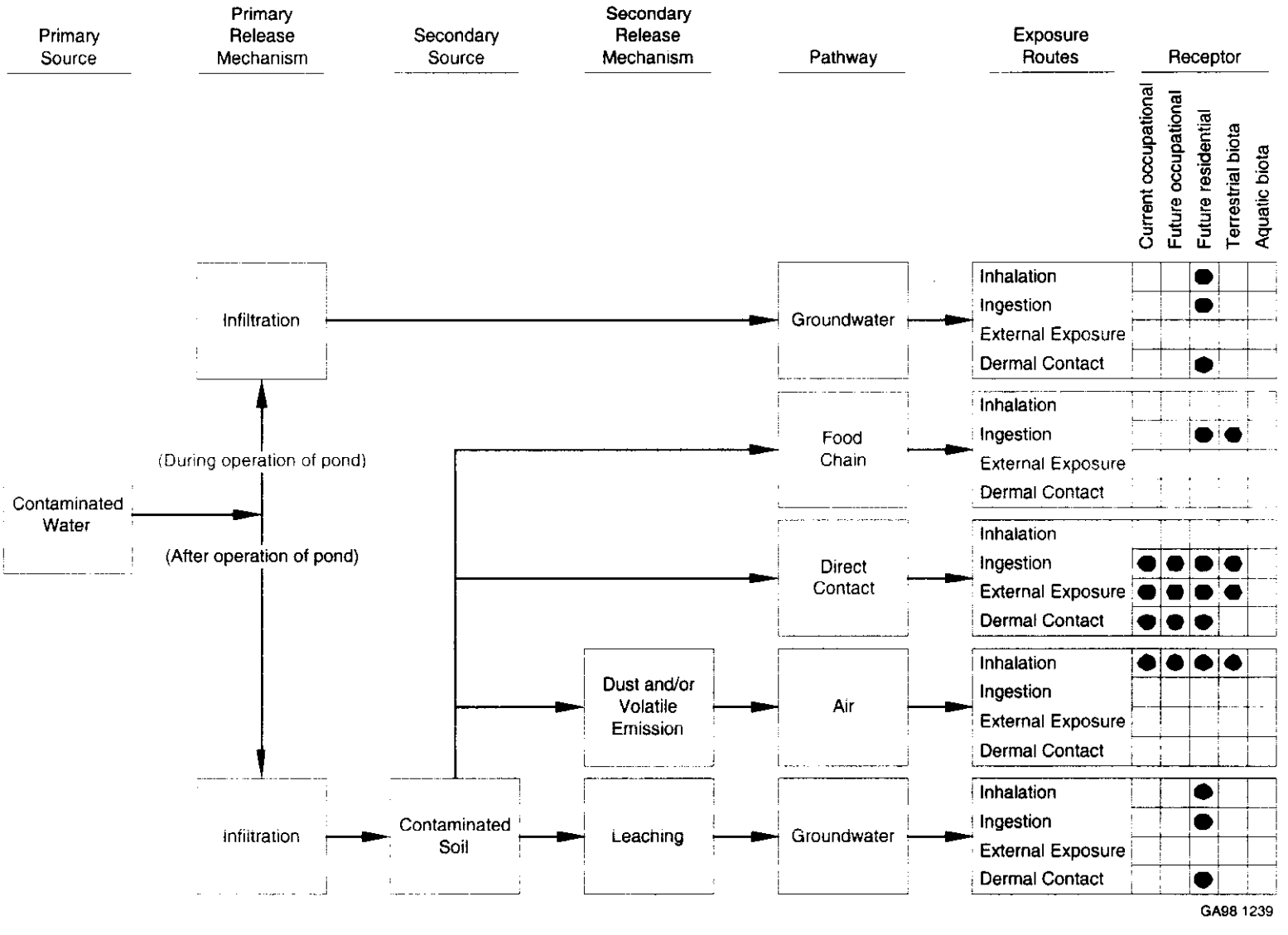


**Figure 6-3.** Conceptual site model for liquid discharge sites at CFA.

For the remainder of this report, sites and contaminants that pass the screening processes will be referred to as "retained" sites and contaminants; all retained sites and contaminants are further evaluated in Sections 6.3 through 6.6. Likewise, sites and contaminants that fail the screening processes will be referred to as "eliminated" sites and contaminants. All eliminated sites and contaminants require no further evaluation in the BRA.

WAG 4 includes 52 potential hazardous waste release sites such as the landfills, drainage ponds, dry wells, french drains, underground storage tanks, and spill areas. Wastes at these release sites originated from offices, laboratories, maintenance shops, storm and floor drains, and parking lots. Only historic release sites that have been identified at WAG 4 are considered in the OU 4-13 site and contaminant screening processes.

The following sections discuss the site and contaminant screening methodologies. These methodologies are graphically summarized in Figure 6-4.

### 6.2.1 Site Screening Methodology

Table D-1 presents a list of WAG 4 release sites. All of the sites listed in this table are considered in the site screening process.

The following steps are used to screen release sites:

1. The contaminant sampling information for all WAG 4 sites is compiled.

2. Sites that have not been evaluated by previous risk assessments (i.e., new sites) are identified.

3. Sites that are identified as requiring no further action in the FFA/CO are eliminated.

4. Sites for which a contaminant source does not exist are eliminated. These are sites that have either never contained any contamination, or have had all contamination removed.

5. Sites for which risk was determined to be insignificant by previous risk evaluation activities (e.g., Track 1, Track 2, or other investigations) are eliminated. Risk and HI levels of 1E–06 and 1.0, respectively, are used for this screening step; fewer than 10 release sites are eliminated by this step.

6. Sites containing known contaminants are retained for further evaluation against the contaminant screening criteria.

The site screening steps are discussed in further detail in the following sections.

***6.2.1.1 Step 1.*** The contaminant sampling information for all WAG 4 sites is compiled and presented in Appendix B. In the FFA/CO, WAG 4 is divided into 13 OUs, and these OUs are further divided into individual release sites. Appendix D, table D-1 contains a summary of the information on the 52 potential release sites.

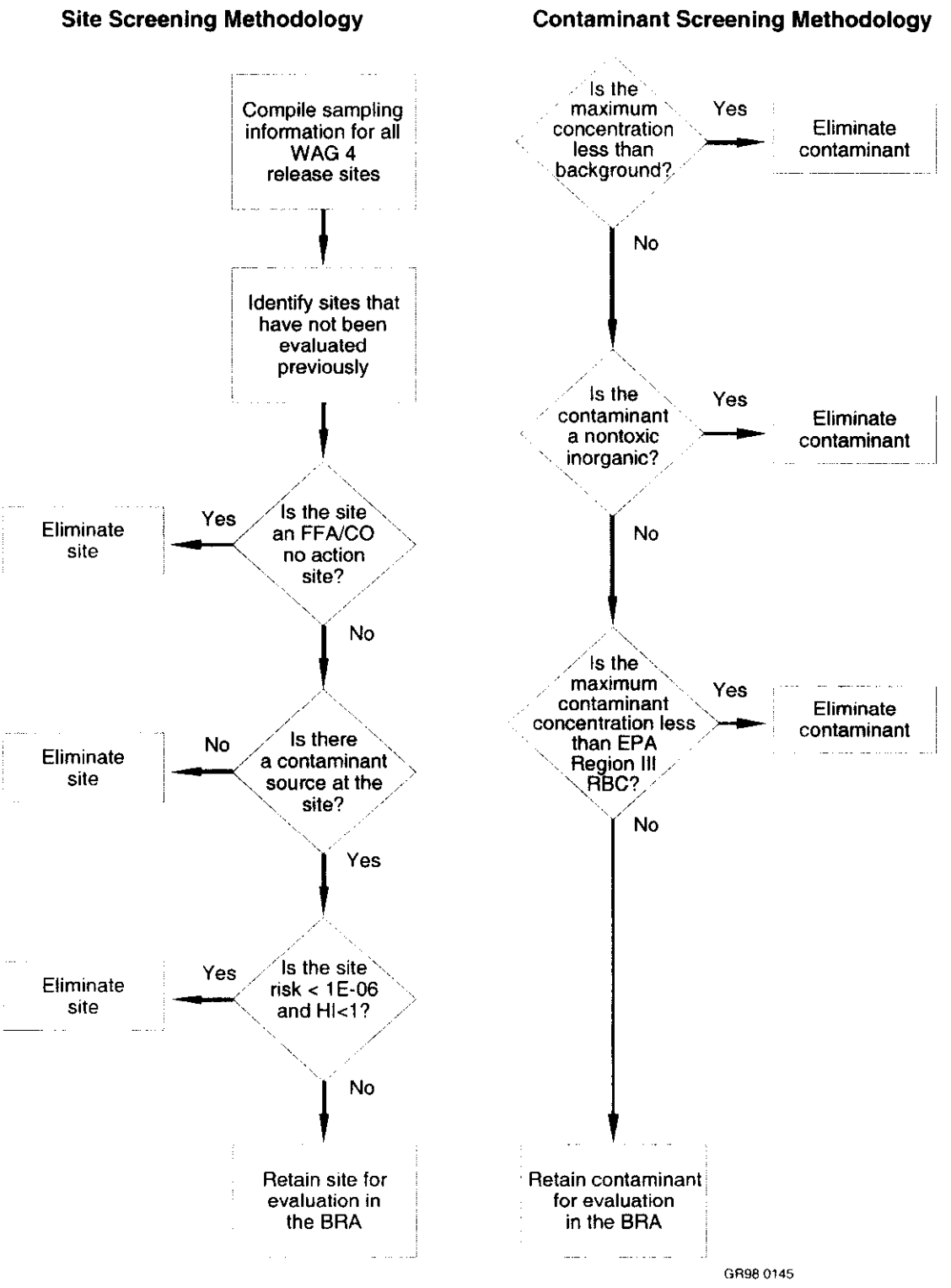


**Figure 6-4.** Site and contaminant screening methodologies.

***6.2.1.2 Step 2.*** All sites that have not been evaluated by previous risk assessments (for example the Track 1 or Track 2 investigations), (DOE-ID 1994) are identified. In general, only sites that are not listed in the FFA/CO are identified by this screening step. These sites are not subject to Step 5 of the site screening process.

***6.2.1.3 Steps 3 through 5.*** No action, no-source, and low-risk sites are eliminated. Sites that are designated as no action in the FFA/CO, and as a result were not assigned to an OU, are eliminated by Step 3. Sites for which analytical data indicates there is no contaminant sources, or where remedial action has removed all sources, are eliminated in Step 4. Finally, Step 5 eliminates all sites that have been shown to have risks less than 1E-06 and HIs less than 1.0 by Track 1 or Track 2 investigations. Screening criteria of 1E−06 and 1.0 are used because these levels are the minimum acceptable human health risk and HQ values cited in the NCP (see Section 6.5). Of the 52 actual or potential release sites at WAG 4, 34 release sites are screened (i.e., eliminated) in steps 3-5. Table D-2 Appendix D shows which sites have been eliminated from further evaluation, and provides the justification for elimination of those sites.

***6.2.1.4 Step 6.*** All sites that are not eliminated in Steps 3 through 5 of this process are retained for further evaluation (i.e., contaminant screening). These sites are shown in Table D-2, Appendix D.

### 6.2.2 Contaminant Screening Methodology

Contaminant screening was conducted for all sites that were not eliminated in the site screening process discussed in Section 6.2.1. The contaminant screening methodology is depicted in Figure 6-4. The methodology initially involves compiling all sampling data for each retained site. The sampling results used in the contaminant screening are from various Track 1, Track 2, and other investigation reports, verification sampling following removal actions, characterization data during implementation of the RI/FS Work Plan, and the Integrated Data Environmental Management System (IDEMS) database. The IDEMS database manages INEEL sampling data, and ensures that the data, methods, and data validation qualifiers for all organic, inorganic, and radiological data are consistent.

Two contaminant screens were conducted. Initial contaminant screening was performed as part of the OU 4-13 RI/FS Work Plan, as discussed in Section 6.2.2.1. The purpose of the initial contaminant screening was to make a preliminary determination of COPCs that may require risk evaluation. In addition, as discussed in Section 4, Nature and Extent of Contamination, supplemental contaminant screening was performed in this RI/BRA. The purpose of the supplemental contaminant screen was to refine the results of the initial contaminant screen presented in the OU4-13 RI/FS Work Plan in order to determine which of the retained sites contain COPCs that require quantitative risk evaluation in the RI/BRA. The supplemental contaminant screen was necessary for the following reasons:

- Removal actions were performed at some of the retained sites (i.e., CFA-06, -13, -15, -17/47, -42) after the initial contaminant screen had been conducted. Post-removal analytical data was therefore available for these sites following confirmatory soil sampling.

- Additional site characterization of CFA-04 and -08 was performed after the initial contaminant screening had been conducted. Additional analytical data was therefore available for these sites.

- More recent risk-based screening concentrations (EPA 1997a) have been issued. All sites and COPCs retained based on the OU 4-13 RI/FS Work Plan were re-screened using the more recent risk-based screening concentrations.

The methodologies used to conduct each of these contaminant screens are described below in further detail.

***6.2.2.1 RI/FS Work Plan Initial Contaminant Screening.*** In Section 3.4 of the Work Plan, initial contaminant screening was performed at each of the retained sites to identify COPCs. The following steps were used to screen contaminants in the Work Plan. Each screening step was applied to each contaminant that has been detected at each retained site. As a result of the screening process, individual contaminants may have been eliminated at one retained site, but retained at other sites.

1. Contaminants that are not detected are eliminated from further evaluation.

2. Contaminants that are tentatively identified compounds (TICs) are eliminated from further evaluation. These compounds are discussed in the uncertainty analysis of the BRA (Section 6.6).

3. All contaminants with maximum concentrations that were less than or equal to INEEL background concentrations are eliminated from further evaluation. Background concentrations are taken from *Background Dose Equivalent Rates and Surficial Soil Metal and Radionuclide Concentrations for the Idaho National Engineering Laboratory* (Rood et al. 1995). If a specific background concentration was not available, the contaminant was retained and other screening criteria were considered.

4. Based on EPA guidance (EPA 1991a), six inorganic constituents that are not associated with human toxicity under normal circumstances (aluminum, calcium, iron, magnesium, potassium, and sodium) can routinely be eliminated from analysis in the human health risk assessment. However, these chemicals were retained for analysis in the risk assessment, if the maximum detected concentration was greater than 10 times the background concentration, or if quantitative toxicity information exists.

5. Contaminants that do not exceed the risk-based soil concentrations are eliminated from further evaluation. RBCs are the concentrations that correspond to a calculated lifetime cancer risk of 1E-06, or a HQ of 1. The RBCs used to screen contaminants were calculated using the soil ingestion, soil inhalation, and external exposure pathways. The risk-based screening method was applied by comparing the maximum detected soil concentration for a given contaminant at a given release site against the most restrictive concentration for the contaminant shown in the RBC evaluation.

Chemicals that did not meet the screening criteria outlined above were retained as COPCs for further evaluation in the supplemental contaminant screen, discussed in Section 6.2.2.2. If no COPC's were identified for a retained site using this screen, the site was eliminated from further evaluation.

***6.2.2.2 Supplemental Contaminant Screening.*** Supplemental contaminant screening was performed to refine the results of the initial contaminant screen, based on the availability of new analytical data and the publication of more current risk-based screening concentrations. Only those sites and chemicals that were retained as COPC's as a result of the initial contaminant screen were evaluated in the supplemental contaminant screen. The supplemental contaminant screen was comprised of the following two screening steps:

1. Comparison of the maximum detected contaminant concentration to the respective background concentration.

2. Comparison of the maximum detected contaminant concentration to the respective EPA Region III (1997a) risk-based screening concentration. A contaminant was retained as a COPC if the maximum detected concentration exceeded both screening criteria. Only those contaminants identified as COPCs in the RI/FS Work Plan were included in the supplemental contaminant screen.

The supplemental screens for each of the retained sites are presented in Appendix C. The tables show the maximum concentration of each contaminant found at each retained site, respective background and risk-based screening concentrations, and whether the screening process eliminates a given contaminant. The tables also indicate which of the COPCs are retained for evaluation in the BRA. If no COPCs are identified for a site, the site is eliminated from further evaluation.

The supplemental contaminant screen indicates that COPCs are not present at CFA-26, -46, and -52 to a depth of 3 m (10 ft) bgs. However, these sites are retained for groundwater pathway evaluation in the risk assessment because past activities at these sites resulted in suspected subsurface releases below a depth of 3 m (10 ft) bgs.

The results of the site and contaminant screening process are summarized in Table 6-1. All of the retained sites and COPCs that will be evaluated at those retained sites are listed in this table.

Although removal actions occurred at CFA-13, CF-15, CFA-17/47, CFA-07, CFA-12, and CFA-42, post-removal analytical data indicate that residual contamination still exists at these sites at levels above background or risk-based screening concentrations. However, as discussed in Section 4 (Nature and Extent of Contamination), for each of these sites, residual contamination is only detected in the basalt. Inclusion of these sites for quantitative evaluation in the BRA is conservative because the soil at these sites has already been remediated.

### 6.2.3 Data Uncertainties

There is a possibility that a contaminant may be present at a retained site without being detected in a site investigation. These unidentified contaminants would not be included in the contaminant screening evaluation. The possibility of important contaminants escaping identification is considered small because most site sampling investigations are designed to detect all contaminants that may have been released at a site, and a review of the processes that generated the contamination at each retained site was included as part of the BRA data evaluation process described in Section 6.1.1.

An aspect of the BRA that tends to exaggerate risk results is the evaluation of contaminants with background concentrations that produce calculated risks in excess of 1E–06 (see Section 6.5 for risk characterization methodology). One example of this type of contaminant is arsenic. Arsenic is commonly detected in INEEL soils at concentrations that are slightly higher than the arsenic background screening concentration of 7.4 mg/kg presented in Rood (1995); however, measured concentrations generally are within the range of measured background levels at the INEEL and are therefore likely to be naturally occurring. In addition, arsenic is not associated with known waste producing processes at WAG 4. For these reasons, arsenic was eliminated from further evaluation in the BRA at five sites (i.e., CFA-05, CFA-06, CFA-07, CFA-08, CFA-10). Arsenic is retained as a COPC at CFA-04 because past waste producing activities at CFA-04 may have resulted in concentrating naturally occurring levels of arsenic at the site.

**Table 6-1.** Summary of WAG 4 Release Sites and COPCs Considered in the BRA.

| OU | Site Code | Site Description | COPCs | Contaminated Medium or Media |
|---|---|---|---|---|
| 4-02 | CFA-13 | Dry Well (South of CFA-640) | Benzo(a)anthracene, benzo(b)fluoranthene, benzo(g,h,i)parylene, lead, Am-241, Ra-226, U-235, U-238, Zr-95 | Subsurface soil |
| | CFA-15 | Dry Well (CFA-679) | Ra-226 | Subsurface soil |
| 4-05 | CFA-04 | Pond (CFA-674) | Arsenic, mercury, Cs-137, U-234, U-235, U-238 | Surface soil and subsurface soil |
| | CFA-17/47 | Fire Department Training Area (bermed) and Fire Station Chemical Disposal | Benzo(g,h,i)perylene, phenanthrene | Subsurface soil |
| 4-07 | CFA-07 | French Drains E/S (CFA-633) | Ag-108 m, Cs-137, lead, Pu-238 | Subsurface soil |
| | CFA-12 | French Drains (2) (CFA-690) [South Drain only] | Ag-108 m, Am-241, Ba-133, Cs-137, Eu-152, U-235, U-238 | Subsurface soil |
| 4-08 | CFA-08 | Sewage Plant (CFA-691), Hot Laundry Drain Pipe (CFA-49) and Drainfield | Cs-137, Pu-239/240, Ra-226, U-235 | Surface soil and subsurface soil |
| 4-09 | CFA-10 | Transformer Yard Oil Spills | Lead | Surface soil |
| | CFA-26 | CFA-760 Pump Station Fuel Spill | Chlorodifluoromethane, phenol, di-n-butylphthalate, TPH-diesel[a] | Subsurface soil |
| | CFA-42 | Tank Farm Pump Station Spills | Phenanthrene | Subsurface soil |
| | CFA-46 | Cafeteria Oil Tank Spill (CFA-721) | Benzene, TPH-diesel, ethylbenzene, toluene, xylenes | Subsurface soil |
| 4-11 | CFA-05 | Motor Pool Pond | Ac-228, Am-241, Bi-212, Bi-214, Cs-137, lead, Pb-212, Ra-226, Tl-208 | Subsurface soil |
| 4-13 | CFA-52 | Diesel Fuel UST (CFA-730) at Bldg CFA-613 Bunkhouse | Tetrachloroethene; 1,1,1-trichloroethane; TPH-diesel[a] | Subsurface soil |

a. Contaminant screening for this site was performed in the OU 4-13 RI/FS Work Plan, a screening table for the site is not included in Appendix C.

## 6.3 Exposure Assessment

The objective of the human health exposure assessment is to quantify the type and magnitude of potential exposures to human receptors from the COPCs that are present or are migrating from the site. This section outlines the methodologies and assumptions used to calculate the potential daily exposure to each Site COPC. The results of the exposure assessment are combined with chemical-specific toxicity information (Section 6.4) to characterize potential risks posed by WAG 4 COPCs (Section 6.5).

Quantifying receptor intake consists of the following four major steps:

- Identification and characterization of exposed populations
- Evaluation of exposure pathways
- Estimation of contaminant concentrations at points of exposure for the following exposure media:
  - Soil
  - Air
  - Groundwater.
- Estimation of contaminant intakes.

Each of these steps is discussed in the following sections.

### 6.3.1 Identification and Characterization of Exposed Populations

As discussed in the OU 4-13 RI/FS Work Plan, two human receptor populations could potentially be exposed to contaminants found at, or originating from, WAG 4: workers and residents. Potential risks to workers and residents are assessed quantitatively in this BRA. Assumptions associated with evaluating potential exposures and risks to these two receptor populations are discussed in the sections below. Workers. Because WAG 4 is currently operational, workers at the site are potential receptors. Potential risks to the following two occupational exposure scenarios are assessed in the BRA:

1. A current occupational scenario that lasts for 25 years from the present.
2. A future occupational scenario that starts in 100 years and lasts for 25 years.

Both the current and future occupational scenarios are evaluated assuming radioactive decay. For nonradionuclides, it is conservatively assumed that chemical degradation does not occur; hence the potential risks presented for the future occupational scenario from exposure to nonradionuclides are equivalent to those calculated for the current occupational scenario.

***6.3.1.1 Residents.*** For the purposes of the BRA, residential development is considered as a potential future use of the site, and a future residential exposure scenario is quantitatively evaluated in the BRA.

The residential exposure scenario evaluated in the BRA considers a future resident who moves to the site in 100 years and lives there for 30 years, the reasonable upper-bound residence time (EPA 1991b). Because the nearest single-family residence is currently located several miles from the boundary of WAG 4 and there are no plans for residences to be built at WAG 4, current residents are not evaluated in the BRA.

Groundwater pathway risks are calculated at 100 years in the future for use in the 100-year residential exposure scenario. Groundwater risks for each COPC are also calculated at the time of the maximum groundwater concentration of each COPC, as long as the maximum concentration occurs before 10,000 years in the future. Section 6.3.3.3 presents a more detailed discussion of the groundwater pathway analysis.

The future residential scenario is evaluated assuming radioactive decay for radionuclides. For nonradionuclides, it is conservatively assumed that chemical degradation does not occur.

***6.3.1.3 Future Land Use.*** Future land use at the INEEL will most likely remain industrial. Other potential, but less likely INEEL land uses include agriculture and the return of areas onsite to an undeveloped state. A land use document was developed in an effort to assist DOE in identifying the issues regarding probable future land use (DOE 1996). According to this document, CFA facilities are planned to continue with new development through the 100-year time-frame and will be maintained as a central location for all support functions at the INEEL.

### 6.3.2 Evaluation of Exposure Pathways

An exposure pathway describes a specific environmental pathway by which a receptor can be exposed to COPCs that are present at or migrating from the site. Five elements comprise an exposure pathway. These elements, shown below, are identified to determine potential exposure pathways at the site:

1. A chemical source
2. A mechanism of chemical release to the environment
3. An environmental transport medium (e.g., air, groundwater) for the released chemical
4. A point of contact between the contaminated medium and the receptor (i.e., the exposure point)
5. An exposure pathway (e.g., ingestion of contaminated groundwater) at the exposure point.

All five of these elements must be met for an exposure pathway to be potentially complete. Information concerning chemical waste sources, chemical release and transport mechanisms, locations of potentially exposed receptors, and potential exposure routes was used to develop a conceptual understanding of the site. This information was summarized schematically in Figures 6-1 through 6-3. In the CSM, potentially complete exposure pathways are designated with a closed circle. Only those exposure pathways deemed to be complete (i.e., where a plausible route of exposure can be demonstrated from the site to the receptor) are quantitatively evaluated in the BRA.

As indicated in the CSM, three categories of sites were retained for evaluation in the BRA as shown in Table 6-2.

Tables 6-3 and 6-4, below, provide a summary of the exposure media and potentially complete exposure pathways associated with these three site types.

***6.3.2.1 Occupational Exposure Pathway Assumptions.*** To evaluate potential occupational risks from exposure to soil, it is assumed that both current and future workers at the sites will only be exposed to contamination from the top 15 cm (6 in) of soil for the soil ingestion, inhalation of fugitive dust and VOC exposure routes. For the evaluation of external radiation exposure, radionuclide activities present in the top 1.2 m (4 ft) of soil will be used. This analysis method is referred to as the occupational nonintrusion exposure scenario, and all occupational exposure scenario analyses in the OU4-13 BRA will include an evaluation of this exposure scenario.

***6.3.2.2 Residential Exposure Pathway Assumptions.*** For the purposes of the BRA, it is assumed that future residents will construct 3 m (10 ft) basements beneath their homes. As a result, all contamination detected in the upper 3 m (10 ft) of each release site will be evaluated for surface pathway exposures. This analysis method will hereafter be referred to as a "residential intrusion scenario," and all residential exposure scenario analysis in the OU 4-13 BRA will include the residential intrusion assumption.

In general, the residential exposure scenario only evaluates adult exposures. The reason for this limitation is that the risk results presented in the BRA are calculated using very conservative exposure assumptions. These assumptions most likely cause the calculated risk results to overestimate the actual risks to even sensitive subpopulations, such as children, that would result from exposure to the site's contamination.

The exception to this rule is associated with the soil ingestion exposure route described in Section 6.3.3.1. Under this exposure route, six years of childhood soil ingestion and 24 years of adult soil ingestion are included in the contamination intake calculation. Soil ingestion is the most critical exposure route for children who may someday live at WAG 4 because of the relatively large amount of soil that children may ingest.

### 6.3.3 Estimation of COPC Concentrations at Points of Exposure

Exposure point concentrations are one of several parameters required to estimate the intake of chemicals by a human receptor. Exposure point concentrations were calculated in accordance with EPA guidance for calculating concentrations terms (EPA 1992b). The calculated exposure point concentrations correspond to the upper 95 percent confidence limit (95% UCL) of the mean for each of the COPC data sets evaluated. As part of the analysis, all data sets are assumed to have lognormal distribution.

EPA (1989a) risk assessment guidance recommends consideration of the positively detected results together with the non-detected results (i.e., sample quantitation limits). Following this guidance, for all results reported as "non-detect," one-half of the sample quantitation limit was assumed as a conservative proxy concentration for each sample with a non-detect result.

**Table 6-2.** Retained Site Categories.

| Site Category | Corresponding Retained Site |
|---|---|
| Surface Soil | CFA-10 Transformer Yard Oil Spills |
| | CFA-17 Fire Department Training Area (bermed) and CFA-47 Fire Station Chemical Disposal |
| UST and Buried Waste | CFA-07 French Drain E/S [CFA-633] |
| | CFA-12 French Drains [CFA-690], south drain only |
| | CFA-46 Cafeteria Oil Tank Spill [CFA-721] |
| | CFA-52 Diesel Fuel UST [CFA-730] at Building CFA-613 Bunkhouse |
| Liquid Discharge | CFA-04 Pond [CFA-674] |
| | CFA–05 Motor Pool Pond |
| | CFA–08 Sewage Plant [CFA-691], Septic Tank [CFA-716], and Drainfield |
| | CFA-13 Dry Well (South of CFA-640) |
| | CFA-15 Dry Well (CFA-674) |
| | CFA–26 CFA-760 Pump Station Fuel Spill |
| | CFA–42 Tank Farm Pump Station Spills |

**Table 6-3.** Summary of Current and Future Occupational Exposure Media and Pathways.

| | Occupational Exposure Medium– Occupational Exposure Pathway | | | |
|---|---|---|---|---|
| Site Type | Soil – Ingestion | Soil—Dermal Contact | Soil— External Exposure | Air—Inhalation of VOCs and Particulates |
| Surface Soil | x | x | x | x |
| UST, Buried Sites | | | x | |
| Liquid Discharge | x | x | x | x |

x = Potentially complete exposure pathway; will be quantitatively evaluated in the BRA.

**Table 6-4.** Summary of Future Residential Exposure Media and Pathways.

| | Residential Exposure Medium—Residential Exposure Pathway | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Site Type | Soil— Ingestion | Soil— Dermal Contact | Soil— External Exposure | Soil – Home Grown Produce Ingestion | Air– Inhalation of VOCs and Particulates | Ground Water– Ingestion | Ground Water— Dermal Contact | Ground Water— Inhalation of VOCs |
| Surface Soil | x | x | x | x | x | x | x | x |
| UST, Buried Sites[a] | x | x | x | x | x | x | x | x |
| Liquid Discharge[a,b] | x | x | x | x | x | x | x | x |

x = Potentially complete exposure pathway; will be quantitatively evaluated in the BRA.

[a] Evaluation of CFA-07, CFA-08 STD, CFA-26, CFA-42, CFA-46, and CFA-52 is limited to groundwater pathways because soil contamination is limited to depths greater than 10 ft below ground surface (bgs) (see Sections 4.1.13, 4.1.15, and 4.1.18, respectively).

[b] Evaluation of CFA-05 is limited to groundwater pathways.

If the calculated 95% UCL of a chemical in a medium-specific data set exceeds the maximum concentration detected in that data set, EPA (1989a) recommends that the maximum detected concentration be selected as the exposure point concentration. Exceedance of the maximum detected concentration typically occurs when dilution effects have resulted in reporting of very high sample quantitation limits (i.e., non-detect values) or if a limited number of sample results are available (e.g., less than ten).

Site surface areas and soil volumes, and chemical-specific properties [i.e., molecular weights, radionuclide half-lives, soil to water partition coefficients ($k_d$), solubilities, octanol-water partition coefficients ($K_{ow}$), organic carbon partition coefficients ($K_{oc}$), diffusivities, Henry's Law Constants, and plant uptake factors (PUFs)] are required to estimate exposure point concentrations. Table D-3 summarizes the surface areas and soil volumes that were used to calculate COPC exposure point concentrations. Table D-4 provides a summary of chemical-specific property values that were used to calculate COPC exposure point concentrations.

The depths of contamination used to evaluate the identified potentially complete soil exposure pathways are based on guidance given in the *INEL Track-2 Investigation Manual* (DOE-ID 1994). Contaminant exposure point concentrations for soil are calculated for a range of depth intervals to evaluate the different exposure scenarios and pathways, as shown below.

| Depth Interval | Exposure Scenario and Pathway(s) |
|---|---|
| 0 to 0.15 m (0 to 6 in.) | Occupational scenario: soil ingestion, inhalation of fugitive dust, inhalation of volatiles |
| 0 to 1.2 m (0 to 4 ft) | Occupational scenario: external radiation exposure |
| 0 to 3 m (0 to 10 ft) | Residential scenario: all soil pathway and air pathway exposure routes |
| All sample results included, regardless of depth | Residential scenario: all groundwater pathway exposure routes |

For each of these soil depth intervals, 95% UCL concentrations were calculated for each COPC based on the methodology described above. The calculated soil concentrations are summarized in Tables D-5 through D-7 by depth interval for each COPC.

The concentration values shown in Tables D-5 through D-7 indicate that a given COPC was detected within the depth interval shown in the table, not that the COPC contamination extends to the bottom of the interval. For example, mercury could have a calculated 0-to-3-m (0-to-10-ft) concentration at a given site even if the site's mercury contamination only extends from 0 to 1.5 m (0 to 5 ft).

The exposure point concentrations for each of the above depth intervals were calculated by volume-weighting 95% UCL concentrations for each of the depth intervals. For example, the 0-to-1.2-m (0-to-4-ft) exposure point concentrations were calculated by determining 95% UCL contaminant concentrations that correspond to soil depths of 0 to 0.5 ft bgs and 0.5 to 4.0 ft bgs. The 95% UCL concentrations for those two soil depth ranges were then volume-weighted using associated depths (i.e., 0.5 ft, 3.5 ft) to calculate a volume-weighted exposure point concentration for the 0–4 ft bgs depth interval. The example algorithm below shows how the exposure point concentration for the 0–4 ft bgs depth interval is calculated.

$$\text{Exposure Point Concentration (0-4 ft)} = \frac{(95\%UCL_{0-0.5\,ft} \times 0.5) + (95\%UCL_{0.5-4.0\,ft} \times 3.5)}{4}$$

Assumptions for the depth of COPC vertical migration are presented in Section 4, Nature and Extent of Contamination. For COPCs that are detected at depths greater than 10 ft bgs, the maximum depth used to calculate exposure point concentrations is based on the assumed vertical migration depth. For example, if mercury is detected at 12 ft bgs but is assumed to migrate 10 ft to a depth of 22 ft bgs, then the 95% UCL calculated for mercury for the > 10 ft depth interval is used to represent mercury concentrations from 10 to 22 ft bgs. Calculation of the exposure point concentration for groundwater pathways would then be based on the following algorithm:

$$\text{EPC (0 - >10 ft)} = \frac{(95\%UCL_{0-0.5\,ft} \times 0.5) + (95\%UCL_{0.5-4\,ft} \times 3.5) + (95\%UCL_{4-10\,ft} \times 6) + (95\%UCL_{10-22\,ft} \times 12)}{22}$$

Volume weighted averaging has the potential for producing underestimation of exposure point concentrations at sites that contain only shallow subsurface contamination (e.g., CFA-10). This potential underestimation would occur if a future receptor were only exposed to the shallow surface soils at the contaminated site, instead of being exposed to soil down to a depth of 3 m (10 ft) bgs. The potential underestimation can be corrected for by multiplying the risk results for a given contaminant at an affected site by the ratio of the contaminant's 0–0.5 ft concentration to its 0–10 ft concentration.

As discussed in Section 6.3.1, for each of the exposure scenarios evaluated, radioactive decay is assumed to occur over the exposure period evaluated. Radioactive decay is estimated using the following equation:

$$C = Co\, e^{-\lambda t} \qquad (6\text{-}1)$$

where

C = concentration at time = t (pCi/g)

Co = initial concentration at time = 0 (pCi/g)

$\lambda$ = decay constant

t = time interval (years)

The decay constant ($\lambda$) is calculated using the contaminant half-life ($t_{1/2}$) in the following equation:

$$\lambda = \ln 2 / t_{1/2} \qquad (6\text{-}2)$$

where

ln2 = natural log of 2

$t_{1/2}$ = half-life of the radionuclide (years)

By substituting $\lambda$ in the first equation, equation (6-1) becomes:

$$C = Co\, e^{-(\ln 2 / t1/2)\, t} \qquad (6\text{-}3)$$

This equation accounts for radioactive decay by estimating the radionuclide concentration at the start of a given exposure, and then calculating the average concentration during the length of the scenario. For example, the concentration of a given radionuclide analyzed in the current occupational exposure scenario is the average concentration that would exist between 0 and 25 years in the future, and the concentration analyzed in the 100-year future residential scenario is the average concentration that would exist between 100 and 130 years in the future. To calculate that average concentration for the future residential scenario, equation (6-3) must be integrated between the start time (t = 100 years) and end time (t = 130). The integral of equation (6-3) is as follows for the residential scenario:

$$C_{average} = C_o \times \frac{\left\{e^{-[(\ln 2 / t1/2)\times 100]} - e^{-[(\ln 2 / t1/2)\times 130]}\right\}}{\left[\frac{\ln 2}{t1/2} \times (130 - 100)\right]}$$

The average radionuclide concentrations over each exposure period evaluated are shown in Tables D-8 through D-12b. These concentrations are used in the intake calculations for each exposure pathway.

The effects of radioactive progeny are only considered by using "+D" SFs in the radionuclide risk calculations (see Section 6.5). Decay and in growth calculations are not performed for complete radionuclide decay chains. The use of "+D" SFs account for risks produced by daughter products that are in secular equilibrium with their parent radionuclides (EPA 1995a).

The following sections describe the methodology used to calculate soil, air, and groundwater exposure point concentrations for the identified COPCs.

***6.3.3.1 Soil Exposure Pathway Methodology.*** The following soil exposure routes are identified in the CSM (Figures 6-1 through 6-3) as potentially complete for the residential and/or occupational exposure scenarios:

- Soil ingestion
- External radiation exposure
- Dermal absorption from soil
- Ingestion of homegrown produce (residential scenario only)

The following sections describe the methodology used to calculate soil exposure point concentrations for these exposure routes. The calculated exposure point concentrations are used to estimate potential exposures from these exposure routes.

***6.3.3.1.1 Soil Ingestion***—Because exposures through the soil pathway are not likely to occur from more than one release site at a time, the soil pathway is evaluated on a site-by-site basis.

As with the air pathway, soil pathway risks and HQs are calculated at 0 and 100 years in the future for the occupational exposure scenario, and at 100 years for the residential scenario.